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(71) Applicant(s)
US Filter Wastewater Group Inc.

(72) Inventor(s)
Warren Thomas Johnson; Gary William Stollery; Bruce Gregory
Biltoft ; David John Cox; Robert James McMahon; David
Wood ; Leon Keith Ernst

(74) Agent/Attorney
BALDWIN SHELSTON WATERS, Level 21, 60 Margaret Street, SYDNEY NSW
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<p>(21) International Application Number: PCT/AU00/00352</p> <p>(22) International Filing Date: 20 April 2000 (20.04.00)</p> <p>(30) Priority Data: PP 9850 20 April 1999 (20.04.99) AU</p> <p>(71) Applicant (for all designated States except US): USE FILTRATION AND SEPARATIONS GROUP INC (USA), 2118 Greenspring Drive, Timonium, MD 21093 (US), 191 Thomas Hill Road, Warrendale, PA 15086, USA</p> <p>(72) Inventors; and</p> <p>(75) Inventors/Applicants (for US only): JOHNSON, Warren, Thomas [AU/AU]; 8 Scarsborough Crescent, Bligh Park, NSW 2756 (AU); STOLLERY, Gary, William [AU/AU]; 5/22 West Market Street, Richmond, NSW 2753 (AU); BILTOFT, Bruce, Gregory [AU/AU]; 51 Park Avenue, Chatswood, NSW 2067 (AU); COX, David, John [AU/AU]; 9/217 Derby Street, Pennith, NSW 2750 (AU); MCMAHON, Robert, James [AU/AU]; 10 Conder Street, Burwood, NSW 2134 (AU); WOOD, David [AU/AU]; 33 Alexandra Street, Hunters Hill, NSW 2110 (AU); ERNST, Leon, Keith [AU/AU]; 73 Anderson Road, Mortdale, NSW 2223 (AU).</p> <p>(74) Agent: BALDWIN SHELSTON WATERS; 60 Margaret Street, Sydney, NSW 2000 (AU).</p>		<p>(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published With international search report.</p>	
<p>(54) Title: MEMBRANE FILTRATION MANIFOLD SYSTEM</p> <p>(57) Abstract</p> <p>A membrane filtration manifold (1) for connecting a filter submodule (2) including one or more elongate bundles of semipermeable polymeric fibres. The manifold (1) includes a housing (3) and connecting collar (4) connected with said housing (3). The collar (4) is adapted to receive and locate the submodule (2), where the submodule has a connecting sleeve (5) with a locking formation (6). The submodule (2) can be secured at one end to the collar (4) by a clip means (7) adapted to engage both the collar and the locking formation to prevent axial withdrawal of the submodule from the collar. Also disclosed is a membrane filtration apparatus (25) including a filter submodule (2) including one or more elongate bundles of semipermeable polymeric fibres. The apparatus further includes a membrane filtration manifold removably connected at one end of said filter submodule (2) and a basepiece (27) removably connected to the other end of said filter submodule.</p>			

TITLE: MEMBRANE FILTRATION MANIFOLD SYSTEM

TECHNICAL FIELD

The present invention relates to membrane filtration manifold systems. More particularly, the invention relates to membrane filtration manifold systems for hollow fibre membrane filters comprising elongate bundles of hollow fibre membranes, wherein feed to be filtered is fed to the outside of the bundles of fibres and filtrate is extracted from the end or ends of the fibre lumens. The systems also preferably incorporate a cleaning facility for periodic cleansing of the feed surfaces of the fibres.

The invention has been developed primarily for use in a membrane filtration system 10 which is open to atmospheric pressure and will be described hereinafter with reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use.

BACKGROUND ART

Any discussion of the prior art throughout the specification should in no way be 15 considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

Typical prior art filtration manifolds are employed in filtration systems of the type described above. These filtration systems generally include elongate tubular cartridges enclosing a bundle of the hollow fibre membranes. Manifold or header arrangements are 20 used to connect the cartridges, usually at one or both ends, these manifolds acting to separate and divert the respective flows of the contaminated feed, filtrate and cleaning fluid through the system. In this regard, cross-flow systems typically have two feed manifolds (inlet and re-circulation outlet) and one or two filtrate manifolds. In cross-flow filtration systems of the prior art the feed stream to be filtered flows tangential to or across the surface 25 of the membrane. This generates a sweeping action at the membrane surface, keeping the surface cleaner. Conversely, systems configured for dead end operations utilise only one feed inlet manifold and one filtrate _____

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outlet manifold during filtration mode. Further, these prior art manifolds or header arrangements are often configured to facilitate the construction of modular two or three dimensional cartridge arrays.

Most typically, the prior art filtration systems, as previously described, are closed to the atmosphere. In such systems, fluid to be filtered, hereinafter referred to as feed, is fed under positive pressure to the filters. In order for this type of system to operate effectively, the elongate tubular filtration cartridges are encased in pressure tight housings. Such housings are then connected to a manifold system which both separates the feed from the filtrate and supports the pressure tight housing. The manifold system may also serve to introduce cleaning fluid to the filtration system.

Prior art filtration systems, as previously described, may also be open to the atmosphere. Typically in such systems, feed is drawn through the membranes under negative pressure. This is achieved by applying a negative, or suction, pressure on the filtrate side of the membrane. Such systems tend to employ less infrastructure and capital works compared with systems closed to the atmosphere as they do not require components that are able to contain relatively higher pressures. For example, there is no need to encase filtration cartridges in individual pressure tight housings in systems open to atmosphere. Typically in these systems, the filtration cartridges are merely substantially immersed in an open tank containing the feed. In such systems it is desirable that an appropriate manifold be provided to both support the filter cartridges and to allow the filtrate to be drawn from the filter while separating the feed from the filtrate. Similarly, as with closed systems, such a manifold may also serve the purpose of supporting a cleaning fluid system.

Prior art filtration systems and their associated filtration cartridges referred to above are often a complex configuration of pipes and parts which are difficult and time

consuming to assemble. Further more, the actual manifold system components of the prior art filtration systems are often a complex assembly of parts in themselves.

The prior art filtration systems described above also require regular testing to assess system integrity. Non-integrity may be due to failure of individual filtration membrane hollow fibres, 'o'-rings or other system components. Integrity testing often requires the removal of either individual system components or filtration cartridges. This removal is often difficult in typical prior art filtration manifolds. Furthermore, as previously discussed, typical prior art filtration manifolds may contain many complex parts. It then follows that integrity testing of these parts can also be time consuming.

10 It is an object of the present invention to provide a filtration manifold system of the kind herein described which overcomes or ameliorates at least some of the deficiencies of the prior art or at least offers a useful alternative thereto.

SUMMARY OF THE INVENTION

According to one aspect of the invention there is provided a membrane filtration manifold for connecting a filter submodule of the kind including one or more elongate bundles of semipermeable polymeric fibres, said manifold including:

15 a housing; and

at least one submodule connecting collar connected with said housing, said collar being adapted to receive and locate said submodule having a connecting sleeve with a

20 locking formation whereby the submodule can be secured at one end with the collar by a clip means adapted to engage and at least in part surround both said collar and said locking formation to prevent axial withdrawal of said submodule from said collar.

25 Preferably, said locking formation includes a circumferential flange formed on said sleeve.

Also, in a preferred form, the housing and collars of the manifold include

passageways for fluid communication between the housing and collars. Further preferably, the housing includes a removable cap for fluid-tight sealing engagement with the housing.

For preference, the clip means is self-actuable, that is, the clipping action is provided by the features of the clip means itself rather than by co-operation with a further 5 integer.

According to a second aspect of the invention there is provided a membrane filtration apparatus including:

a filter submodule of the kind including one or more elongate bundles of semipermeable polymeric fibres;

10 a headpiece removably connected at one end of said filter submodule; and a basepiece removably connected to the other end of said filter submodule; said headpiece being a membrane filtration manifold according to the first aspect of the invention.

According to a third aspect of the invention there is provided a membrane filtration 15 apparatus bank including:

a plurality of membrane filtration apparatuses according to the second aspect of the invention;

a filtrate conduit connected to at least one membrane filtration apparatus; and a cleaning fluid conduit connected to at least one membrane filtration apparatus.

20 Preferably, the module groups are arranged in an upright position, said filtrate conduit being proximally above said headpieces and said cleaning fluid conduit being proximally above said basepieces.

According to a fourth aspect of the invention there is provided a membrane filtration 25 apparatus array including a plurality of membrane filtration apparatus banks according to the third aspect of the invention connected in parallel by an array filtrate conduit.

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According to another aspect of the invention there is provided a membrane filtration apparatus array train including:

a train conduit; and

a plurality of membrane filtration apparatus arrays according to the fourth aspect

5 of the invention connected in fluid communication with said train conduit.

BRIEF DESCRIPTION OF THE FIGURES

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

10 Figure 1 is a perspective view of a membrane filtration manifold according to the invention;

Figure 2 is another perspective view of the membrane filtration manifold of Figure 1;

Figure 3 is a sectional view showing a submodule connected to a manifold collar by a locking clip;

15 Figure 4a is an isometric view of the preferred embodiment of the clip;

Figure 4b is an isometric view of the preferred embodiment of the clip of Figure 4a;

Figure 4c is an isometric view of an alternate embodiment of the clip;

20 Figure 5 is a cross sectional side elevation of the locking clip of Figure 4a;

Figure 6a is a detail view of the collar;

Figure 6b is another detail view of the collar;

Figure 7a is a plan view of an embodiment of the connecting sleeve for filtration modules;

25 Figure 7b is a sectional view of the connecting sleeve of Figure 8a taken on line

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A-A of Figure 7a;

Figure 7c is a side elevation of the connecting sleeve of Figure 7a;

Figure 8a is a plan view of an alternate embodiment of the connecting sleeve for filtration modules;

5 Figure 8b is a sectional view of the connecting sleeve of Figure 8a taken on line

B-B of Figure 8a;

Figure 8c is a side elevation of the connecting sleeve of Figure 8a;

Figure 9a is a perspective view of a cap;

Figure 9b is another perspective view of the cap of Figure 9a;

10 Figure 10 is a perspective view of the membrane filtration manifold of Figure 1 showing the cap of Figure 9a in use;

Figure 11 is a side elevation of a membrane filtration apparatus bank;

Figure 12a is a side cross sectional elevation of an embodiment of the membrane filtration manifold in basepiece configuration, showing cleaning fluid flow from the 15 cleaning fluid conduit through the basepiece;

Figure 12b is a front cross sectional elevation of an embodiment of the membrane filtration manifold in basepiece configuration, showing cleaning fluid flow from the cleaning fluid conduit through the basepiece;

Figure 13 is a plan view of a membrane filtration apparatus array;

20 Figure 14 is a perspective view showing one membrane filtration apparatus bank in a membrane filtration apparatus array; and

Figure 15 is an isometric view of a membrane filtration apparatus train.

PREFERRED EMBODIMENTS OF THE INVENTION

25 Referring to the drawings, the membrane filtration manifold system includes a

membrane filtration manifold 1 for connecting filter submodules 2 of the kind comprising elongate bundles of hollow fibre membranes. As best shown in Figures 1 and 2, the preferred embodiment of the manifold includes a housing 3 connected with four submodule connecting collars 4.

5 Referring to Figure 3, the collars 4 are adapted to receive and locate submodules 2 having a connecting sleeve 5 with a locking flange 6. In this embodiment, the submodule 2 can be secured at one end with its respective collar 4 by a clip 7 which simultaneously engages the submodule 2 and locking flange 6 to prevent axial withdrawal of the submodule 2 from the collar 4. The locking flange 6 further engages 10 bearingly with a lip 8 of the collar 4. Engaging and releasing the clip 7 enables substantially simple respective assembly and removal of the submodules 2 from the manifold 1. The manifold 1 further includes filtrate passageways 9 for fluid communication between the housing 3 and collars 4 and cleaning fluid passageways 10 for cleaning fluid communication with a cleaning fluid conduit 11.

15 Figures 4a, 4b and 5 show the preferred embodiment of the clip 7. The clip 7 has a substantially cylindrical sidewall 12 with a top and bottom flange 13 and 14, each of which projects radially inwardly from the sidewall 12. The clip 7 is split in a line parallel to the central axis of the submodule 2 to allow radial expansion of the clip when slid axially into and out of locking engagement with the collar 4. Radial expansion is 20 achieved by manually parting a pair of projections 40 provided on the top flange 13 of the clip, on either side of the split respectively. Furthermore, the clip 7 is resiliently biased to enable radial contraction of the clip when the clip snap-lockingly engages with both the submodule 2 and collar 4. When the clip is employed to engage both the submodule and the locking flange, bottom flange 14 locks over the submodule flange 6 25 and top flange 13 bearingly engages with the lip 8. Furthermore, the collar 4 has a

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stepped seat 15 for locking engagement with top flange 13.

Figure 4c shows an alternate embodiment of the clip 7. This embodiment has additional projections 41 to aid in the manual removal of the clip 7 from both the submodule 2 and collar 4. The additional projections 41 extend radially from the 5 sidewall 12 of the clip 7, on either side of the split of the sidewall 12.

Figures 7a-c and 8a-c show embodiments of the submodule connection sleeves 5. These Figures show detail of the flange 6 and 'o'-ring seat channel 17 features of the connection sleeves 5. One side 18 of the flange 6 is for bearing engagement with the collar 4 and a second side 19 is for locking engagement with the 10 clip 7. Further, the embodiment of the submodule connection sleeve 5 shown in Figures 7a-c, has one channel 17 for use as an 'o'-ring seat, while the embodiment of the submodule connection sleeve 5 shown in Figures 8a-c, has two channels 17 for use as 'o'-ring seats.

The manifold 1 may also include a removable cap 20, for fluid-tight sealing 15 engagement with the housing. The preferred embodiment of the cap, shown in Figures 9a and 9b, includes a disc 21 with an axially extending threaded shaft 22 mounted to its centre on one side. The disc 21 also has projections 23 on the other side to facilitate manual turning of the cap 20. The cap will be described in more detail below.

A radially spaced flange 24 extends axially outwardly from the cap 20 on the 20 same side of the cap as the shaft 22. This flange allows fluid tight sealing engagement of the cap 20 with the housing 1. Figure 10 shows the preferred embodiment of the cap 20 in use.

In another embodiment of the invention shown in Figure 11, a membrane filtration apparatus 25 includes a headpiece 26 and a basepiece 27, each being an 25 embodiment of the membrane filtration manifold 1 as described above, and connected to

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four membrane filter submodules 2. Each headpiece 26 connects to a filtrate conduit 28 allowing fluid communication between each headpiece 26 and the filtrate conduit 28. The cap 20 is not required when the membrane filtration manifold 1 is used as a headpiece 26. Absence of the cap 20 allows fluid communication between the manifold 5 1 and the filtrate conduit 28.

Further, as seen particularly in Figures 12a and 12b, each basepiece 27 is connected to a cleaning fluid conduit 11 allowing fluid communication between each basepiece 27 and the cleaning fluid conduit 11. When the membrane filtration manifold 1 is used as a basepiece 27, the threaded shaft 22 of the cap 20 is threadedly engaged 10 with a corresponding bore on the cleaning fluid conduit 11. Also, in the preferred embodiment, the clip 7 is not required to lock the submodule 2 to the basepiece. This is because the submodule 2 will be held in its respective collar 4 of its basepiece 27, both by gravity and by virtue of the top of the submodule being held in place in its headpiece 26 and a clip 7.

15 In an alternate embodiment of the invention, the shaft 22 is hollow with an internal threaded portion. In this embodiment, rather than threadedly engaging with a bore in the cleaning fluid conduit, the shaft 22 internally threadedly engages with a complementary shaft projecting in a perpendicular direction from the cleaning fluid conduit 11.

20 In another embodiment of the invention, a membrane filtration apparatus bank 29 includes a plurality of membrane filtration apparatus 25 as described above wherein each headpiece 26 is connected to a filtrate conduit 28 and each basepiece 27 is connected to a cleaning fluid conduit 11. Additional stiffening elements 30, as shown in Figure 11, may also be provided therebetween to aid physical stability of the filtration system.

25 Typically, there are eight membrane filtration apparatuses 25 in each bank 29 and the

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apparatuses are arranged in an upright position. When employed in a filtration system, the bank 29 is substantially immersed in the feed, where the feed is contained in a tank 31 with an open top.

Preferably, air is used as the filtration submodule cleaning fluid which flows 5 through the cleaning fluid conduit 11. As best shown in Figures 11, 12a and 12b, the cleaning fluid conduit 11 is proximally above the basepieces 27 and lies in a straight line along the length of the bank 29 in between the collars 4. This allows the cleaning fluid conduit 11 to supply air to the basepieces 27 through a plurality of passageways 10 on the under side of the cleaning fluid conduit 11. Supplying air to the basepieces 27 10 through the underside of the cleaning fluid conduit 11 allows controlled release of the cleaning air, ensuring it is evenly distributed along the entire length of the bank 29.

In another embodiment of the invention, the filtration system includes a 15 membrane filtration apparatus array as shown in Figures 11 and 13 having a plurality of apparatus banks 29 wherein each of the filtrate conduits 28 are connected to an array 15 filtrate conduit 32.

The filtration apparatus banks 29 are further adapted for relatively simple 20 disconnection from the membrane filtration apparatus array. When disconnected, the filtration apparatus banks may be removed from the membrane filtration apparatus array by lifting the bank vertically from the array. Similarly, the banks may also be placed 25 individually into an array by lowering the banks vertically into its predetermined position. This allows for less complicated assembly and disassembly of the arrays and convenient access to submodules disposed in or near the centre of the array.

In a further embodiment of the invention, a membrane filtration array train, as 25 best shown in Figure 15, includes a plurality of membrane filtration apparatus arrays from Figure 14 wherein the array filtrate conduits 32 are connected by a train conduit 33

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such that the array filtrate conduits 32 are in fluid communication with the train conduits 33.

During filtration the tanks 31 are continuously substantially filled with feed which in turn submerges the arrays of filter submodules 2. Pumps 34 draw the feed 5 through the filter submodules 2 producing filtrate. The filtrate under negative pressure from the pumps 34, travels through the manifolds 1, via the filtrate conduits 28, array filtrate conduits 32, and train filtrate conduits 33 and on to the pump. The filtrate then leaves the pump and also the filtration system via a filtrate exit conduit 35.

Although the invention has been described with reference to specific examples 10 and to filtration manifolds used in filtration systems open to atmosphere, it will now be appreciated by those skilled in the art that the invention may be embodied in many other forms including filtration manifolds used in filtration systems closed to atmosphere.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A membrane filtration manifold for connecting a filter submodule of the kind including one or more elongate bundles of semipermeable polymeric fibres, said manifold including:
 - 5 a housing; and at least one submodule connecting collar connected with said housing, said collar being adapted to receive and locate said submodule having a connecting sleeve with a locking formation whereby the submodule can be secured at one end with the collar by a clip means adapted to engage and at least in part surround both said collar and said locking formation to prevent axial withdrawal of said submodule from said collar.
 - 10
 2. A manifold according to claim 1 wherein said housing is in fluid communication with said collar.
 3. A manifold according to claim 1 or 2 wherein said collar has an internal stepped seat for bearing engagement with said secured end of said submodule.
 - 15 4. A manifold according to any one of the preceding claims wherein said locking formation includes a radially outwardly directed circumferential flange formed on said sleeve.
 5. A manifold according to any one of the preceding claims wherein said clip means is cylindrical having a side wall split to define opposed wall edges.
 - 20 6. A manifold according to claim 5 wherein said clip means includes a bottom radially inwardly directed circumferential flange adjacent the bottom of said side wall for bearing engagement with said radially outwardly directed flange formed on said sleeve.
 7. A manifold according to claim 5 or 6 wherein said side wall includes a top radially inwardly directed circumferential flange at or adjacent the top of said side wall for bearing engagement with a complementary step on said collar.
 - 25 8. A manifold according to any one of claims 5 to 7 wherein said clip means includes projections on said side wall adjacent respective said opposed edges.
 9. A manifold according to claim 8 wherein said projections extend longitudinally

from said top flange.

10. A manifold according to any one of claims 6 to 9 wherein said top flange is partially circumferential.
11. A manifold according to any one of the preceding claims wherein said clip is hingedly connectable to said collar.
12. A manifold according to any one of the preceding claims wherein said clip means is mutually interengageable with said collar.
13. A manifold according to any one of the preceding claims wherein said clip means is adapted for over-centred circumferential locking engagement with a said collar.
- 10 14. A manifold according to anyone of the preceding claims wherein said clip is self-actuable.
15. A manifold according to any one of the preceding claims including four submodule connecting collars.
16. A manifold according to claim 15 wherein said collars are disposed in a common plane and have parallel axes.
17. A manifold according to claim 15 or 16 wherein one end of said housing is adjacent each collar and the axis of said housing is parallel to the axes of said collars.
18. A membrane filtration apparatus including:
a filter submodule of the kind including one or more elongate bundles of
20 semipermeable polymeric fibres;
a headpiece removably connected at one end of said filter submodule; and
a basepiece removably connected to the other end of said filter submodule;
said headpiece being a membrane filtration manifold according to any one of the preceding claims.
- 25 19. A membrane filtration apparatus according to claim 18, wherein said basepiece is a membrane filtration manifold according to any one of claims 1 to 17.
20. A membrane filtration apparatus according to claim 18 or 19, wherein said

headpiece is adapted for connection to a filtrate conduit allowing fluid communication between said headpiece and said filtrate conduit and said basepiece is adapted for connection to a cleaning fluid conduit allowing fluid communication between said basepiece and said cleaning fluid conduit.

- 5 21. A membrane filtration apparatus according to claim 20 wherein said collars are configured to allow placement of said cleaning fluid conduit at least partially between two pairs of said collars.
22. A membrane filtration apparatus according to any one of claims 18 to 21 wherein said basepiece includes a removable cap for fluid-tight sealing engagement with the other 10 end of said housing.
23. A membrane filtration apparatus bank including:
a plurality of membrane filtration apparatuses according to any one of claims 18 to 22;
15 a filtrate conduit connected to at least one membrane filtration apparatus; and
a cleaning fluid conduit connected to at least one membrane filtration apparatus.
24. A membrane filtration apparatus bank according to claim 23 wherein said membrane filtration apparatuses are arranged in an upright position, said filtrate conduit being proximally above said headpieces and said cleaning fluid conduit being proximally above said basepieces.
- 20 25. A membrane filtration apparatus bank according to claim 24 wherein said cleaning fluid conduit is at least partially disposed between two pairs of submodule collars and is in fluid communication with said housing.
26. A membrane filtration apparatus bank according to any one of claims 23 to 25 wherein said cleaning fluid conduit is in fluid communication with said basepiece via an 25 aperture in said cleaning fluid conduit to allow cleaning fluid to pass from said cleaning fluid conduit to said submodules via said basepiece.
27. A membrane filtration apparatus bank according to any one of claims 23 to 26 wherein said housing of said headpiece is in fluid communication with said filtrate conduit.
28. A membrane filtration apparatus array including a plurality of membrane filtration

apparatus banks according to any one of claims 23 to 27 connected in parallel by an array filtrate conduit.

29. A membrane filtration apparatus array according to claim 28 wherein said array is adapted for insertion into an open feed tank.

5 30. A membrane filtration apparatus array train including:

a train conduit; and

a plurality of membrane filtration apparatus arrays according to claim 28 or 29 connected in fluid communication with said train conduit.

31. A membrane filtration manifold for connecting a filter submodule of the kind 10 including one or more elongate bundles of semipermeable polymeric fibres substantially as hereinbefore described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings.

32. A membrane filtration apparatus substantially as hereinbefore described with 15 reference to any one of the embodiments of the invention illustrated in the accompanying drawings.

33. A membrane filtration apparatus bank substantially as hereinbefore described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings.

34. A membrane filtration apparatus array substantially as hereinbefore described with 20 reference to any one of the embodiments of the invention illustrated in the accompanying drawings.

35. A membrane filtration apparatus array train substantially as hereinbefore described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings.

25 DATED this 19th day of July, 2002

U.S. FILTER WASTEWATER GROUP, INC.

Attorney: PETER R. HEATHCOTE

Fellow Institute of Patent and Trade Mark Attorneys of Australia

of BALDWIN SHELSTON WATERS

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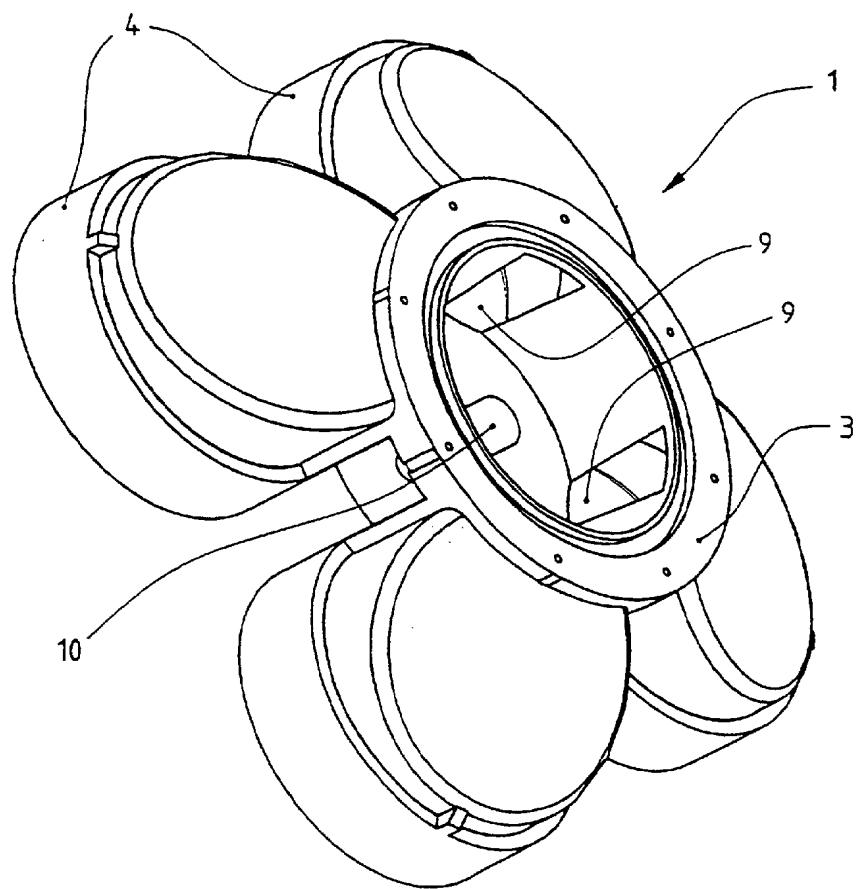


FIG 1

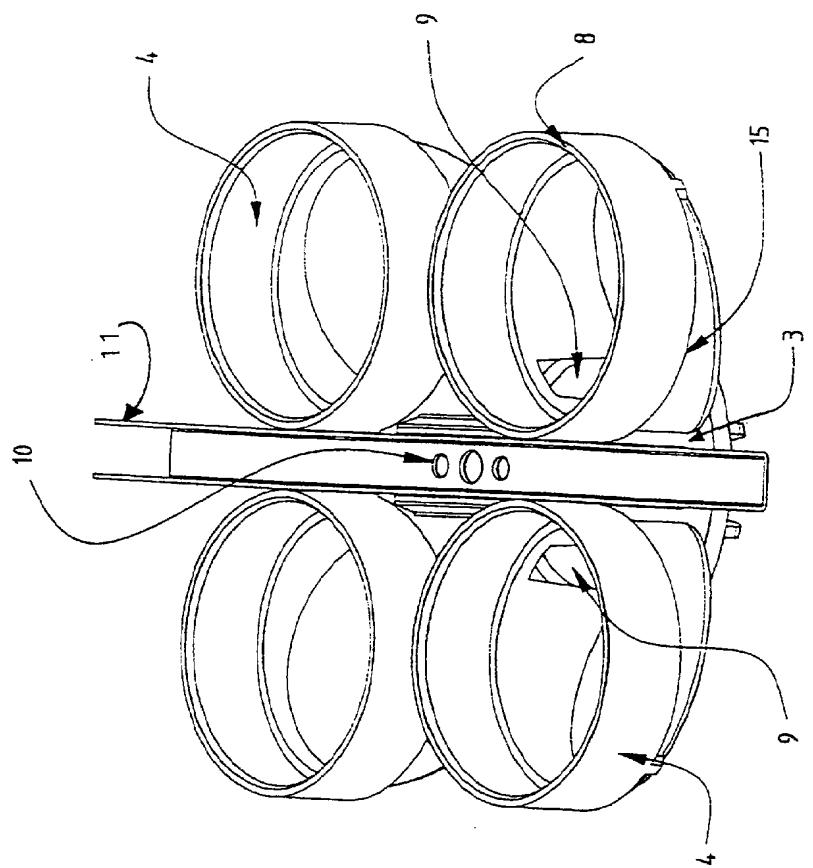
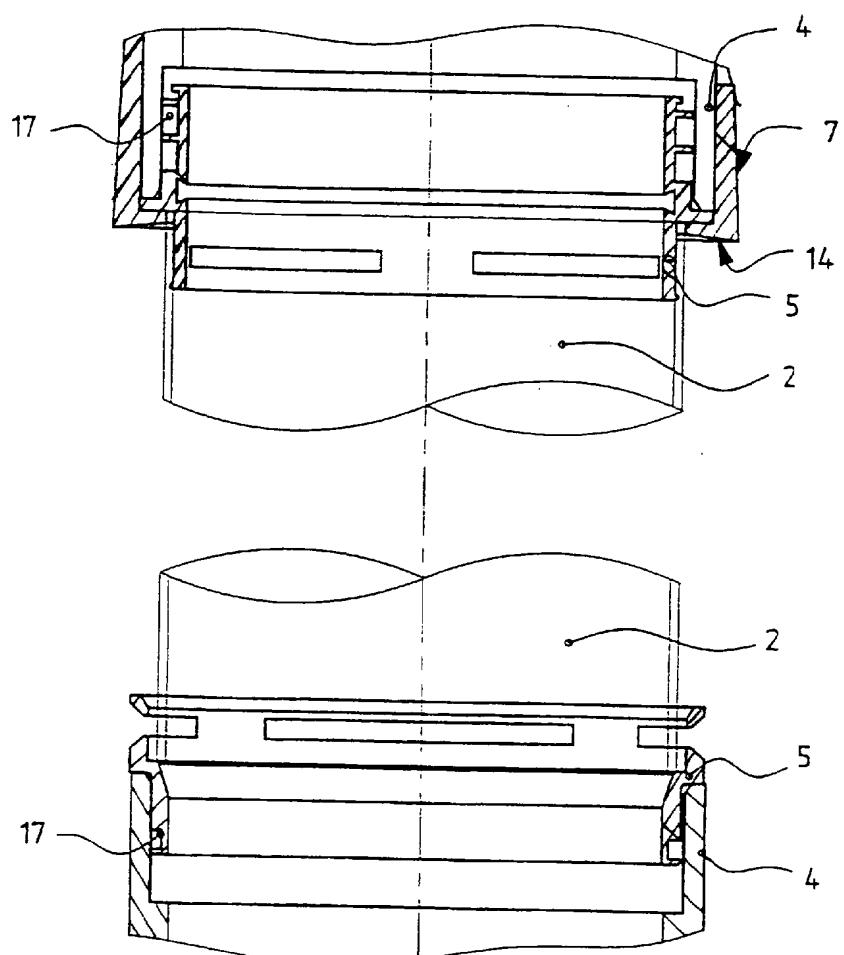


FIG 2

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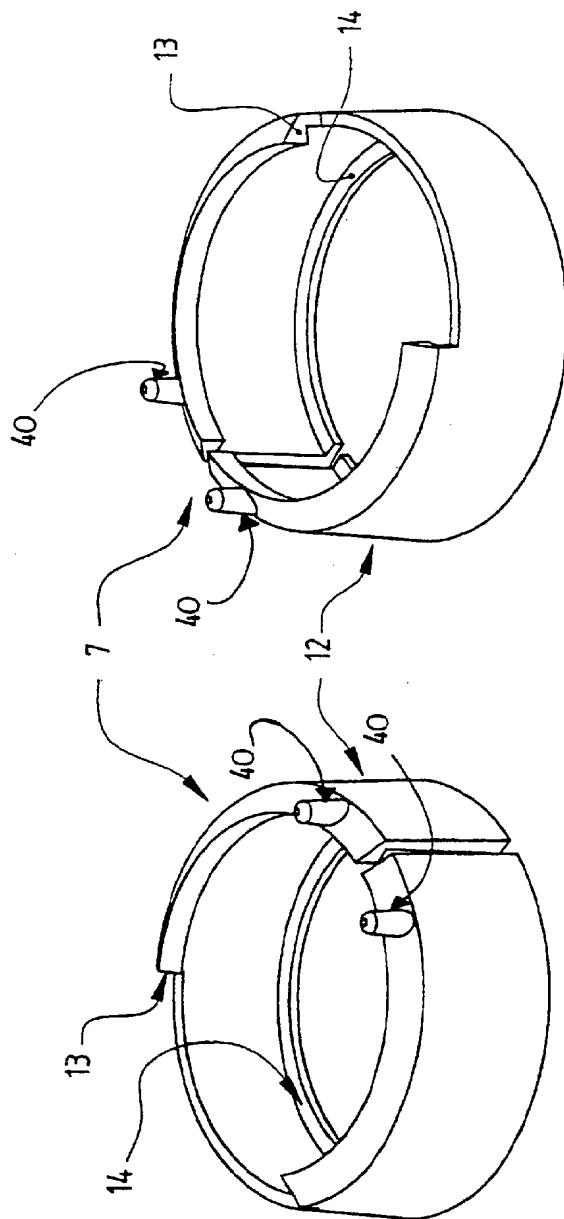


FIG 4b

FIG 4a

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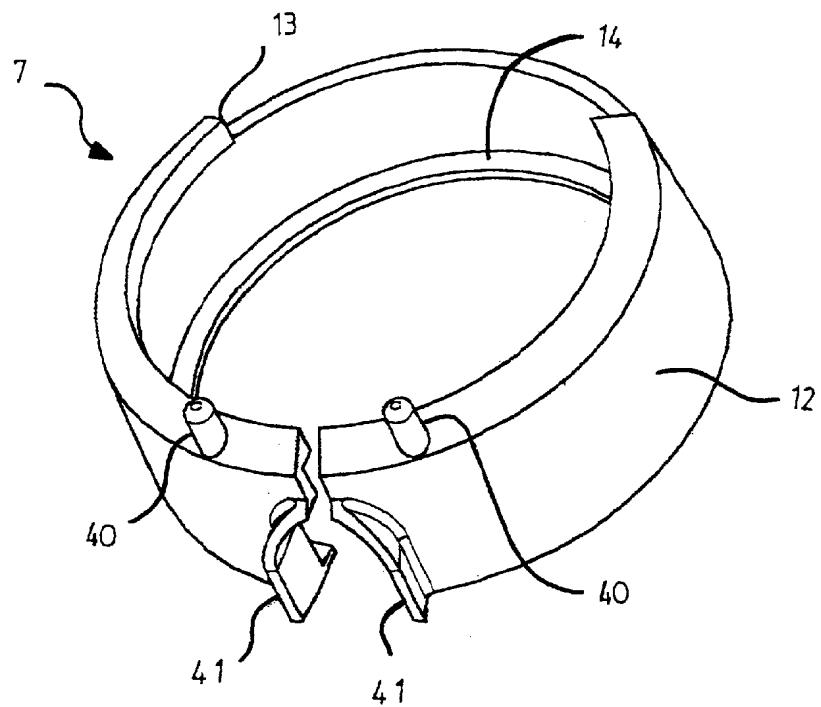


FIG 4c

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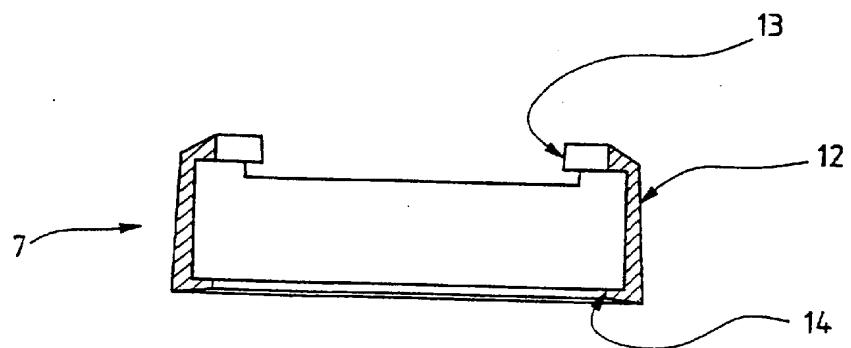


FIG 5

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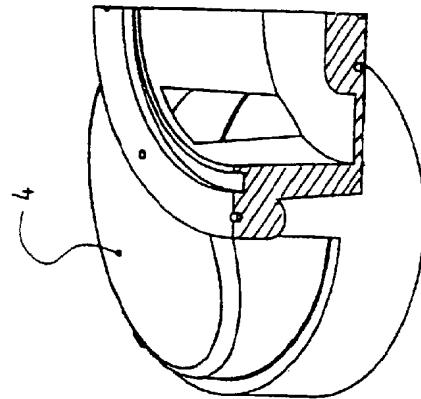


FIG 6b

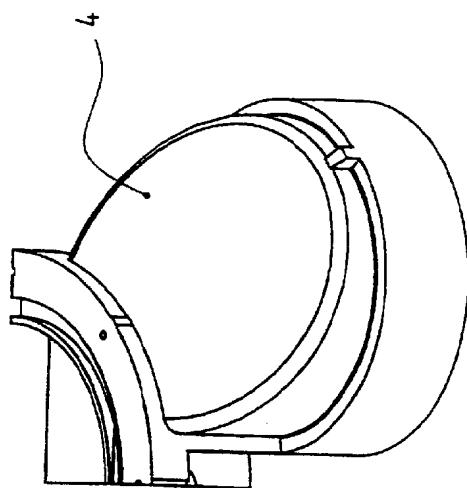
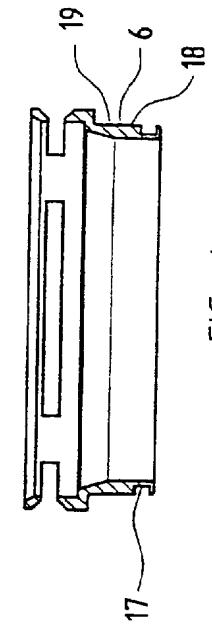
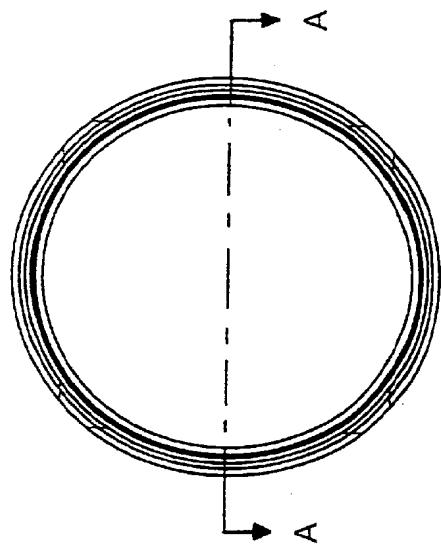
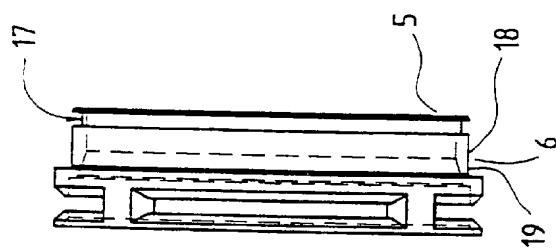
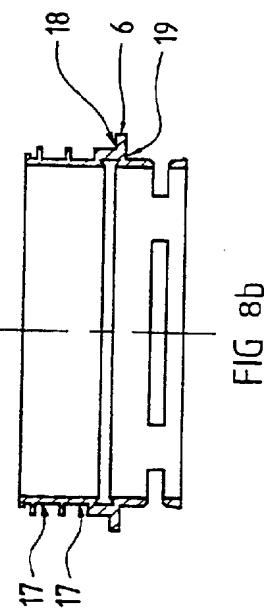
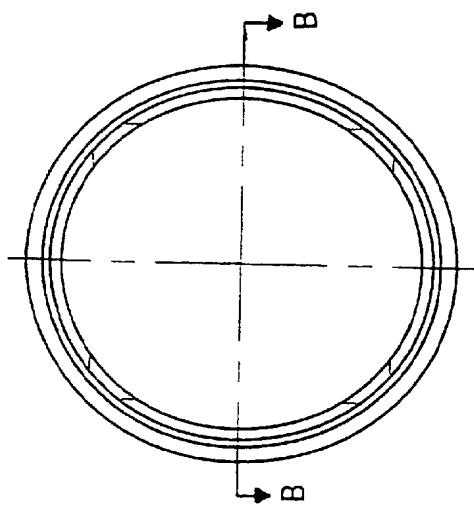
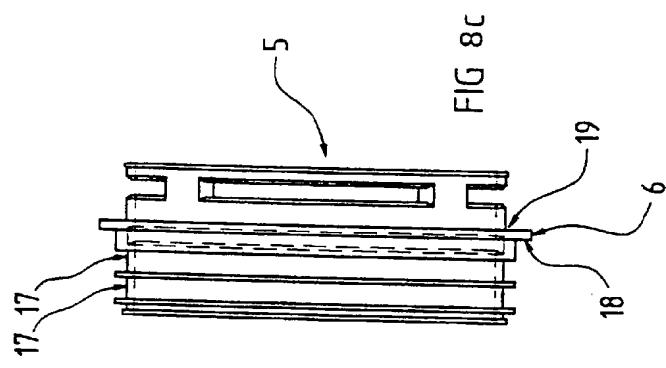


FIG 6a

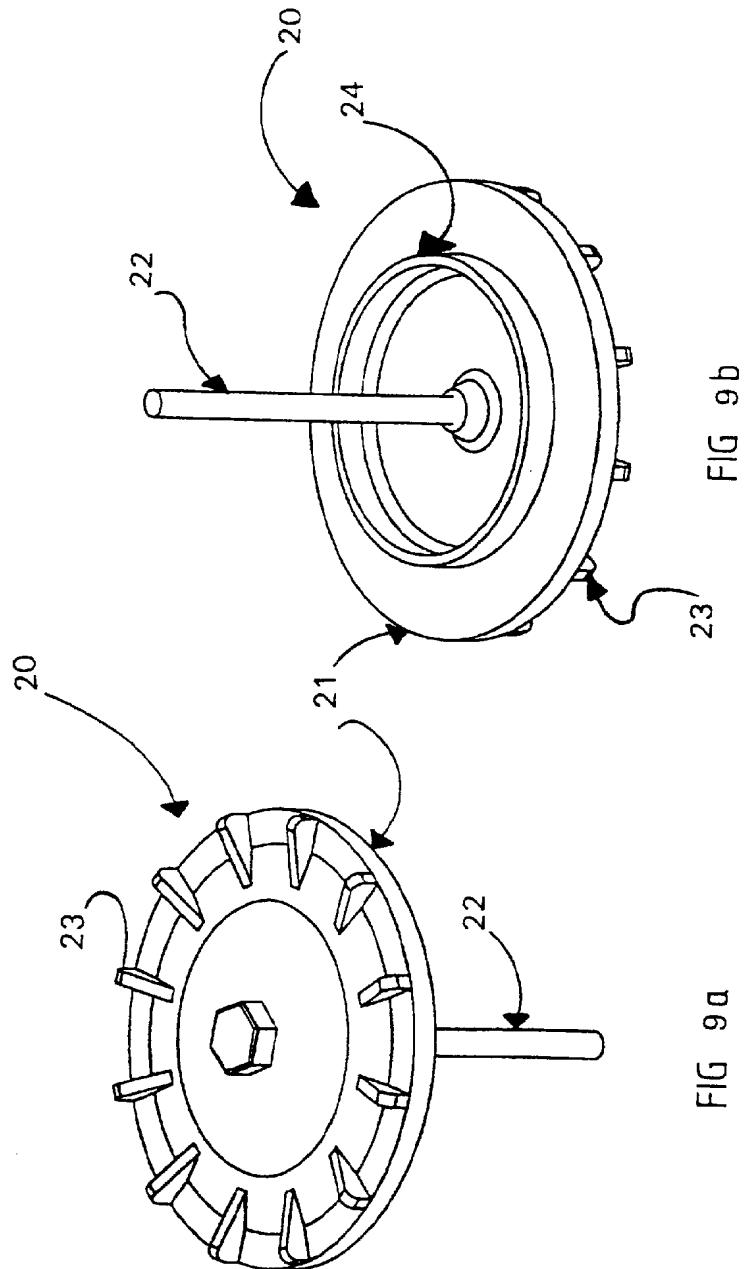
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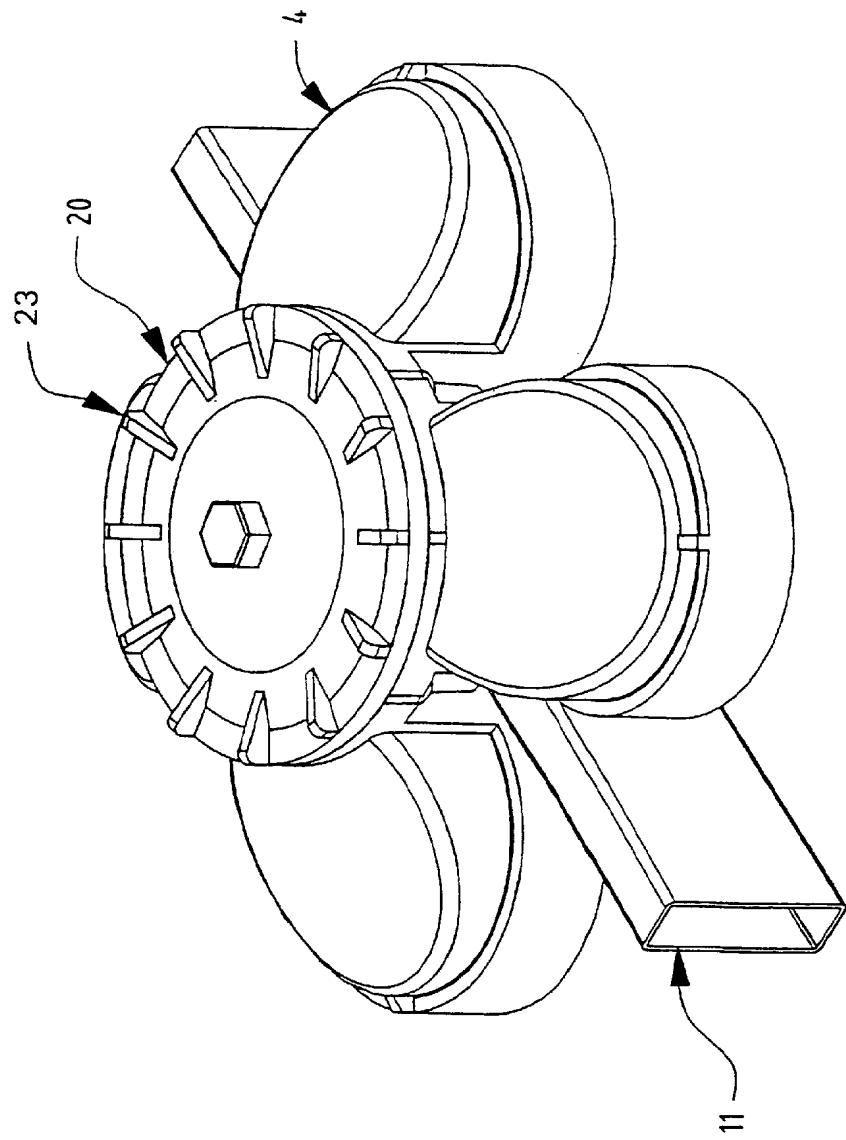


FIG 10

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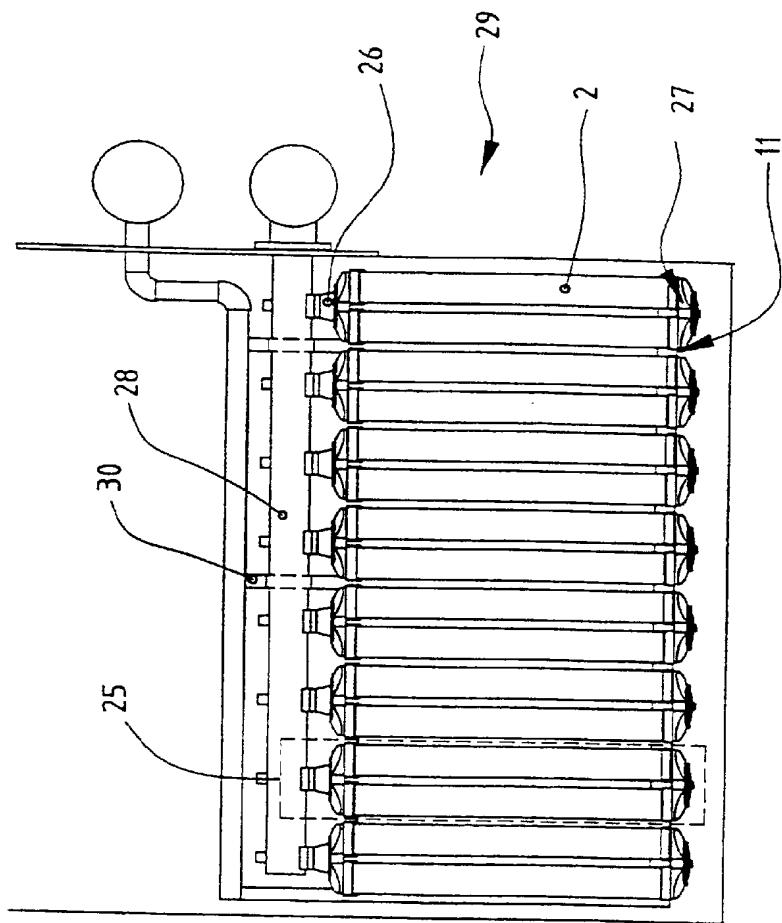


FIG 11

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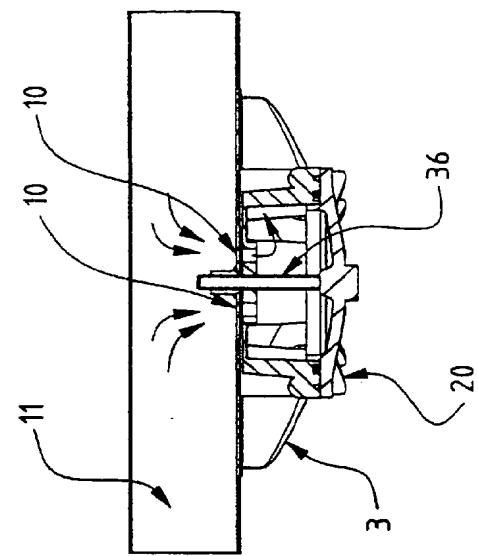


FIG 12b

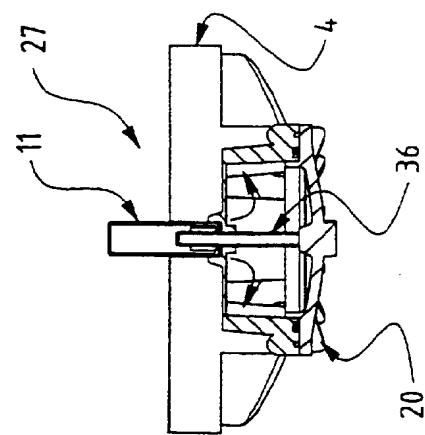


FIG 12a

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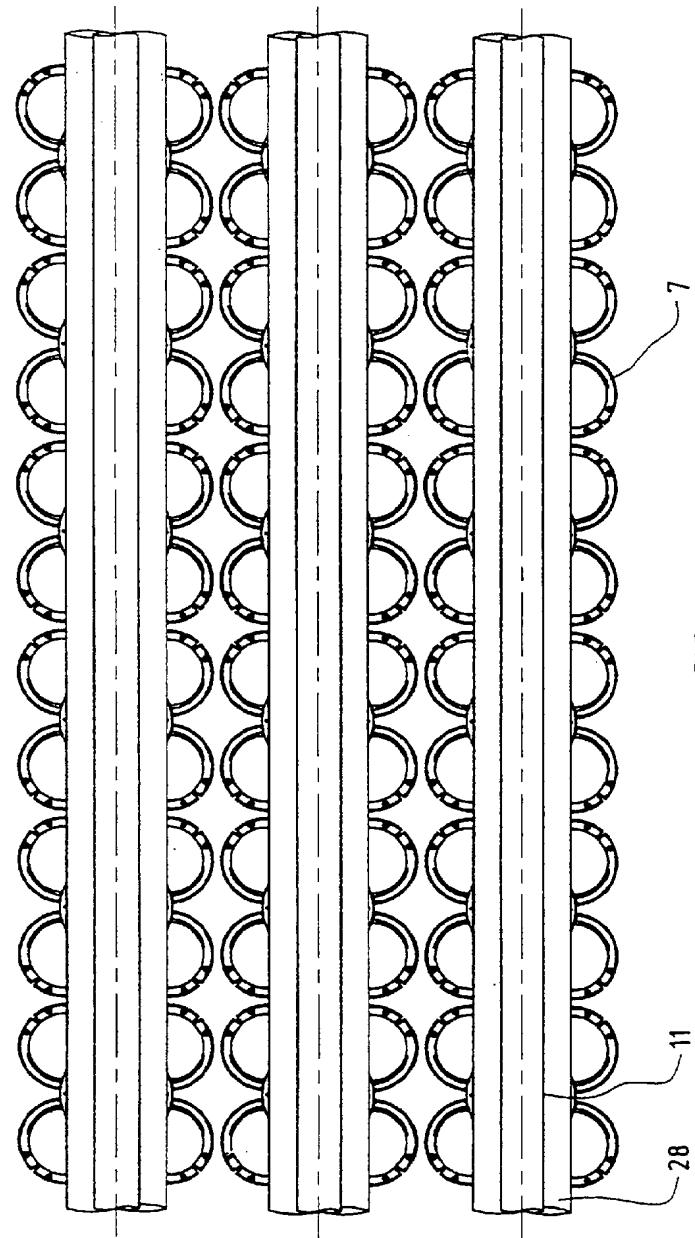


FIG 13

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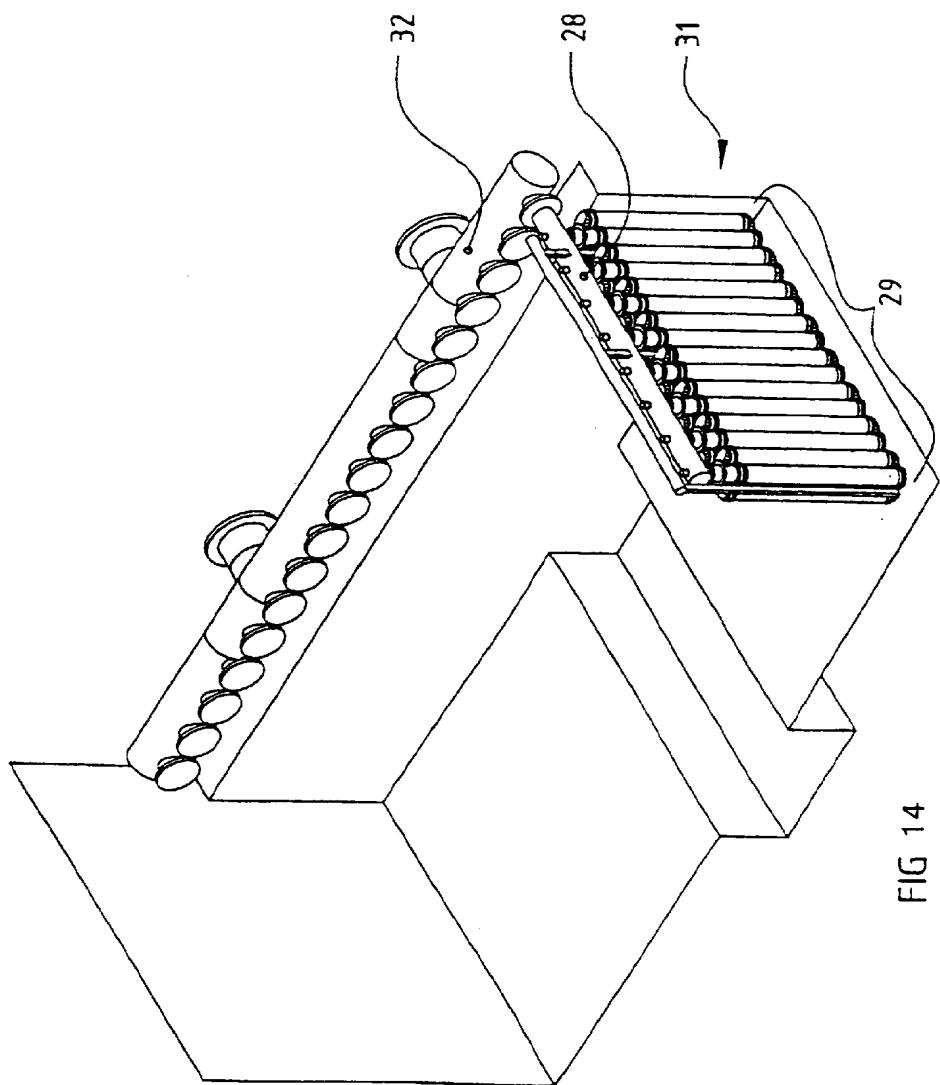


FIG 14

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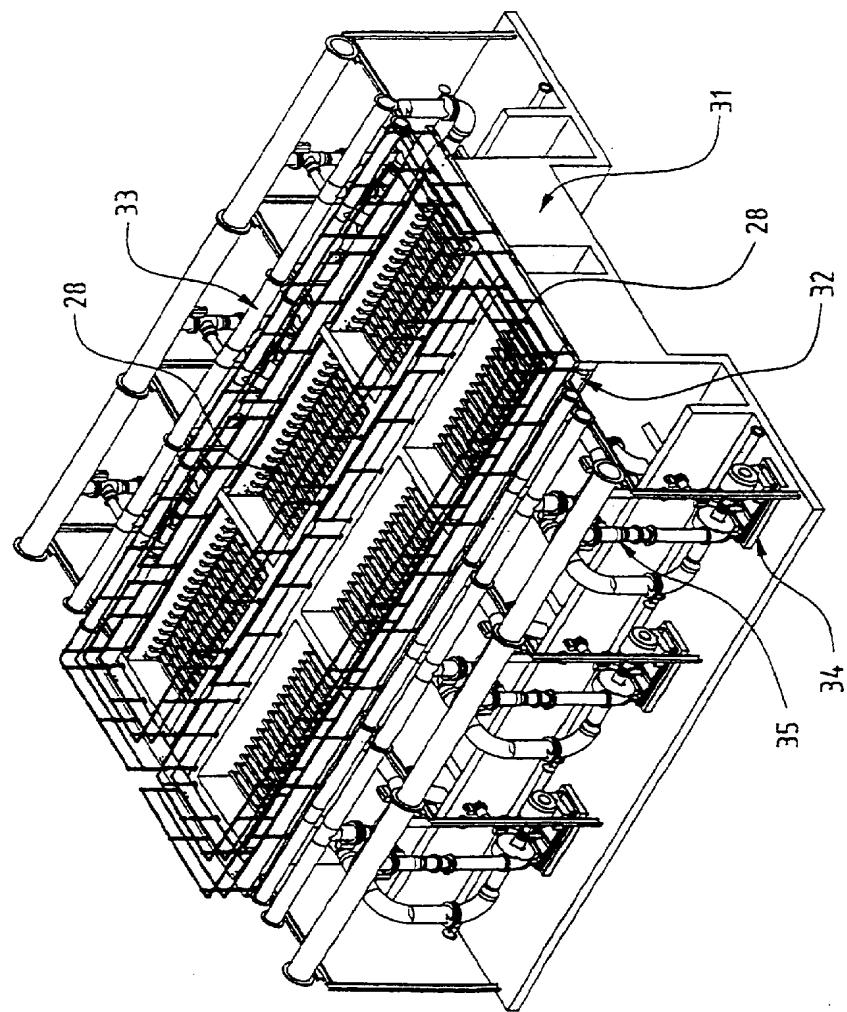


FIG 15